WSRU Vermiculture Program

Manual of operations

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Created March 2012
At Washington State Reformatory

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Introduction:

This user's manual for the vermiculture program is prepared by inmates working at WSRU. Over the course of two years the program has grown from a single worm bed containing 200 worms to a full-fledged program with 13 commercial type flow through bins, a worm population of over 2 million worms receiving over 4,000 pounds of food waste per month. This manual is based upon our experience with the program and the research we have conducted that has helped us. We do not claim to be experts in this field nor do we think that we know everything there is to know about vermiculture. We have however tried very hard to read everything we can find on vermiculture. We have been in regular correspondence with experts from several worm farms as well as professors from The Ohio State University and North Carolina State University. Much of the technical information contained in this manual is from three key sources: Vermiculture Technology, Earthworms, Organic Wastes and Environmental Management,
Manual of On-Farm Vermicomposting and Vermiculture and Processing of Commercial and Industrial Organics and Vermiculture Systems. All three sources are listed in appendix E.

The idea behind this manual is to provide detailed instruction on several aspects of worm bin management. The daily workload is then

summed up in Weekly Management sheets which are found in Appendices B and C.

History and Overview:

In January of 2010, staff and inmates at WSRU began the process of developing a Vermiculture program in conjunction with the sustainability project. Inmates in the hobby shop built 3 small breeding bins using donated wood from family members. The bins were started in February with 200 red wiggler worms (Eisenia Fetida) which were fed scraps from the lunchroom. As the worm population grew, other bins were built using recycled materials. Inmates documented the worm production and feeding schedules and continued to study and collect as much written material as possible on Vermiculture.

Over the next several months the worm population continued to grow but no system was in place to harvest a usable product from the Vermiculture program. The worm beds had become somewhat sour and were becoming an odor problem. In June of 2010 a volunteer position of Vermiculture Coordinator was created. This inmate was tasked with evaluating the current system and working with administration to develop a best practices model for worm production, to eliminate the odor problems, to formulate a strategy for harvesting an organic fertilizer from the worm beds and to increase food processing.

The following objectives were defined:

1. To maximize the current production.
2. To work with the institutional kitchen in obtaining appropriate food scraps that would eliminate or dramatically reduce the odor problems.
3. To develop the worm growing operation into a viable entity that contributes to the sustainability of WSRU and creates potential income generating opportunities.
4. To produce organic fertilizer for the greenhouses and horticulture program.
5. To develop a plan for a vocational training program that would allow inmates to learn the science of Vermiculture and to develop practical skills in sustainable vocations.

Current Operation:

As of December 2011, the worm population was in excess of 2 million worms. At the current rate of production, the population could easily reach 5,000,000 by spring/summer of 2012. Harvesters and casting extractors have been built out of recycled materials. Worm castings and "tea" are being supplied to the greenhouses and exported to other units to use as an organic fertilizer. There are currently, 13 Flow through bins with a surface area of 260 square feet as well as 35 breeder bins and 12 miscellaneous bins. The flow through bins are primarily managed to process as much food waste as possible. The breeder bins house a population of nearly 500,000 worms and are

managed to produce higher proliferation. The laundry cart bins are mainly used as overflow bins and are low management bins.
During the last quarter of 2011, the worms were fed in excess of 10,000 lbs of food waste from the inmate kitchen that otherwise would have been hauled away at considerable expense.

Vermiculture and vermicomposting:

Vermiculture is the culture of earthworms. The goal is to continually increase the number of worms in order to obtain a sustainable harvest. The worms are either used to expand a vermicomposting operation or sold to customers who use them for the same or other purposes.

Vermicomposting is the process by which worms are used to convert organic materials (usually wastes) into a humus-like material known as vermicompost. The goal is to process the material as quickly and efficiently as possible.

These two processes are similar but different. If your goal is to produce vermicompost, you will want to have your maximum worm population density all of the time. If your goal is to produce worms, you will want to keep the population density low enough that reproductive rates are optimized. Both of these processes are used in the WSRU program and will be described in some detail in this manual.

There are three main advantages of vermiculture and vermicomposting that we focus on at WSRU. The first is food waste disposal cost

reduction. Monroe Correctional Complex spends over $60,000 a year to dispose of food waste. By diverting a significant portion of that food waste into the vermiculture program there is the potential for considerable savings. The second advantage is the production of high quality organic fertilizer. Worms produce castings (worm manure) that is very valuable and sought after in the organic gardening market. This fertilizer can be utilized in a solid form that looks like rich soil or made into tea which can be sprayed directly on plants. Worm castings are slow release and will not burn plants.

The third advantage is the production of worms. Red wigglers sell for $20-$40 per pound. At WSRU the vermiculture portion of the program is very important because it provides worms for starting new bins.

Worm Management: The Basics

The most frequently used worm in vermiculture is Eisenia fetida, commonly known as: the "compost worm", "manure worm", "redworm", and "red wiggler" (see Figure 1). This extremely tough and adaptable worm is indigenous to most parts of the world and can be found wherever piles of manure or compost have been left to age for more than a few months.

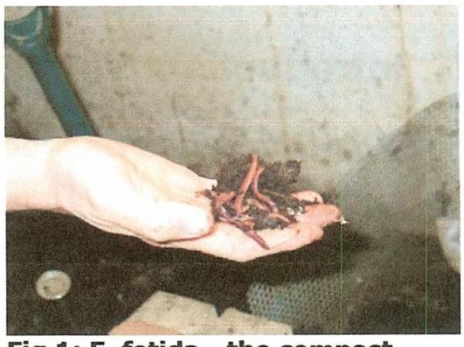


Fig 1: E. fetida - the compost worm

Red wigglers lay cocoons that contain from 1 to 20 worms with an average of 3 to 5. The cocoons are oblong egg shaped and about the size of apple seed. Cocoons are olive green when first hatched and get darker with age until they are brown. Worms can hatch out of the cocoons as early as 21 days if conditions are right but can also take several months to hatch. In proper conditions red wigglers will lay one cocoon per week.

The vermiculture program at WSRU uses red wigglers exclusively. These worms can be purchased commercially or found in any area that has decomposing matter. After lawn clippings, compost or manure is left out in a pile for a few weeks there will be hundreds of red wigglers in the pile.

Compost worms need seven basic things in order to survive and multiply:

1 Bedding;
2 Proper moisture
3 Correct amount and type of food:
4 Sufficient aeration;
5 Maintaining appropriate temperature range.
6 Suitable pH Levels
7 Sufficient space

Bedding:

Bedding is any material that provides the worms with a relatively stable habitat. This habitat must have the following characteristics:

- High absorbency. Worms breathe through their skins and therefore must have a moist environment in which to live. If a worm's skin dries out, it dies. The bedding must be able to absorb and retain water fairly well if the worms are to thrive.
- Good bulking potential. If the material is too dense to begin with, or packs too tightly, then the flow of air is reduced or eliminated. Worms require oxygen to live. Different materials affect the overall porosity of the bedding through a variety of factors, including the range of particle size and shape, the texture, and the strength and rigidity of its structure. The overall effect is referred to in this document as the material's bulking potential.
- Low protein and/or nitrogen content. Although the worms do consume their bedding as it breaks down, it is very important that this be a slow process. High protein/nitrogen levels can result in rapid degradation and its associated heating, creating inhospitable, often fatal, conditions. Heating can occur safely in the food layers of the vermiculture or vermicomposting system, but not in the bedding. It is crucial to always have an area of

bedding that is not saturated with food that the worms can escape to.

Some materials make good beddings all by themselves, while others lack one or more of the above characteristics and need to be used in various combinations.

At WSRU we have found that shredder newspaper and cardboard is readily available and makes great bedding. The idea behind the bedding is that it gives the worms a place to go if the food heats up as well as a place to lay their cocoons.

Proper Moisture:

Virtually all the printed material we read stressed the importance of keeping the beds moist. Worms prefer a moisture content of at least 70% and can tolerate much higher. They will not tolerate dry conditions and will die quickly. Early on in our project one of the bins was allowed to get too dry and we had a very high mortality rate.

We water the bins everyday with a mist sprayer and try to keep the top layer of paper continually moist. A good test is to take a handful of the bedding and squeeze it in your hand. It should produce a few droplets of water. We have made it a practice to keep the beds slightly wetter than most manuals suggest due to the fact that in the prison environment we are never positive when we will be able to return to the project. (Lockdowns, snow days etc.)

One of the problems with keeping the bedding extra wet is that it can produce anaerobic (low oxygen) conditions which will make the beds somewhat smelly. We have overcome this problem by hand turning the beds regularly. (Explained below) This introduces oxygen into the system. We also use shredded corrugated cardboard when available. This is a more labor intensive approach and you won't find it in many books because it is not economically viable but in a prison environment with available labor, it works very well.

Correct amount and type of food:

Compost worms are big eaters. Under ideal conditions, they are able to consume in excess of their body weight each day, although the general rule-of-thumb is 1/2 of their body weight per day. It is important to remember that most commercial worm farms are feeding the worms manure which is already partially decomposed.

For our bins we feed portions of the bed on a scheduled cycle. (Explained in the bin management section.) The most important principle is that the worms must have consumed the majority of the food in the portion of the bed we are feeding before we feed that section again. By feeding only a portion of the bed at a time it allows the worms to move to a cooler section of the bed if the food begins to heat up. This is a constant concern as the worms will not survive if they get too hot for an extended period of time.

The type of food fed is also critical. We only feed fruits, vegetables and leftover hot cereal from the IK. Anything with grease, meat or dairy in it will go sour before it is consumed by the worms. Things like macaroni salad are problematic because it contains mayonnaise. (See Appendix A for a sign we have used with a list of acceptable foods.)

As worms digest their food through a gizzard they also need access to grit. A small handful of sand spread over the top of each bin is more than sufficient.

Sufficient aeration:

The periodicals all stress the importance of oxygen in the bins. Worm beds need a high microbial level to be productive and the types of microbes that worms feed on are very sensitive to oxygen levels.

We found that the best way to maintain good oxygen levels was to use coarsely shredded material such as paper and especially cardboard, We found that the type of shredded paper that is like confetti are not good in the bins. The small pieces clump together and form a ball or get matted on the bottom of the bins. This type of paper remains for months in the bins without breaking down. The prison has a large surplus of cardboard and we found that when ran through a shredder that produces long strands, it was the best material for bedding and allowed good air flow in the bins. We also found that the worms seem to prefer this material. Some literature suggests that cardboard

encourages breeding. The biggest key to getting oxygen into the bins is to turn them on a regular basis. We do this at least weekly with the breeder bins and get a very high reproduction rate.

Another good trick we have used to get air into the bottoms of bins is to take the cardboard egg cartons and apple cartons and put them in the bin over the food when you feed and then cover with paper. This creates a pocket of air.

Maintaining appropriate temperature range:

Although worms can survive in quite cold climates, red wigglers will do best if the bedding is maintained at a temperature between 60 to 80 degrees Fahrenheit.

At WSRU we have 48 bins located inside a heated building which houses the majority of the worms. We also have 2 outside bins.

In the indoor bins we were able to maintain an average temperature of 70 degrees. These bins had a much higher rate of reproduction than the outside bins.

We were able to stimulate hatches in the outside bins by feeding them heavily with melon rinds and then letting them rest. However, the bedding had a much lower egg count than the indoor bins when we did our periodic counts.

When we had hard freezes we put extra bedding and food in the outdoor bins. We have had very little mortality. If outdoor bins are going to be used regularly, soil heating cables are available that will keep the beds from freezing during the coldest parts of winter.

Suitable pH Levels:

We found that there is some discrepancy in the printed materials as to what the best pH level is. Most literature states that worms can tolerate a pH range of 5 to 9. The majority suggest a pH level of 7 (neutral) but other text state that worms like a slightly acidic pH level of 5. Indicators of pH level problems are:

- Worms climbing up and exiting the bin.
- Worms stay low and not coming up to feed.
- Worms mass together in a ball.

At WSRU we had a period of time where the wrong material was being put into a bin due to a failure to properly sort the material. Lunch meats and other high protein items were introduced. This resulted in a very stressed worm population and acidic pH levels. The worms were massed on the top and sides of the bin. We remedied the problem by removing the majority of the worms to another bin. The remainder of the material was then placed in 55 gallon barrel about half full. Clean bedding (shredded newspaper) was then soaked and added to the top of the barrel giving the worms a safe area to escape to. Within a few

days a large population of worms had moved into the bedding and were able to be removed to other beds. Fresh green material (grass clippings etc.) was then added to the barrel and it was allowed to compost for several weeks. Surprisingly, despite the poor conditions, many baby worms were found in the composted material at the end of the process. We found very few adult worms. This indicated to us that the worm cocoons were able to tolerate much worse conditions than the hatched worms.

We have found that the best method for controlling pH is to maintain proper feeding rates and use appropriate foods.

We also found that adding extra bedding of soaked shredded paper to a bin that has become too acidic gives the worms a place to go and tends to neutralize the conditions. The food waste will decompose naturally and the pH will level out.

Some articles suggest the addition of lime which does not hurt the worms as a way to bring the pH level up. As we did not have access to lime we have not tried that method.

pH levels should be checked regularly using a pH monitoring device which has a probe that is put in the soil of the bed and gives a readout.

Sufficient space:

Worms need the right amount of space in order to properly function.

The general rule is that you want to have as much surface space as

possible. We have found literature that suggests a stocking rate of anywhere from 2,000 to 8,000 worms per square foot of surface area depending on what your goals are.

At WSRU we have two separate approaches to worm management. The first approach is focused on breeding as many worms as possible. The second approach is focused on getting the worms to consume as much food waste as we can without the beds going bad. Both of these approaches will be discussed in detail in this manual. The appropriate space for each management approach differs.

In the breeder bins we have approximately 5.5 square feet of surface area in a relatively shallow bin. We try to have between 3,000 to 4,500 worms per square foot. We are constantly managing and splitting these bins to get optimum reproduction rates.

The flow through bins have 20 square feet of surface area with a very deep bin. We strive to have up to 7,500 worms per square foot in these bins. As the worms have lots of room to move up and down in the deep bin, we can stock at a higher rate to get a higher feeding rate. Most literature states that worms stocked at this higher rate do not reproduce as often and that is our reason for having two styles of bins with different purposes.

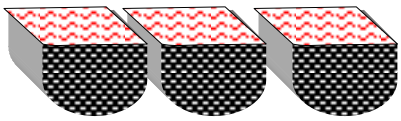
Worm Management: The Bins

We have experimented with numerous styles of worms bins.

The first bins we used were small stackable units like the ones commonly sold for home use. These performed adequately but are much too small for large scale production.

Numerous other styles were tried until we reached the three designs that we currently have in production.

Breeder Barrel Bins



This is a plastic 55 gallon barrel cut in half and mounted on a movable rack with hinges that allow the half barrel to be tilted up on the rack. Each barrel bin has 5.5 square feet of surface area and is capable of holding 20-30,000 worms.

The management model for this bin is designed to stimulate high reproduction rates. This is accomplished through a relatively high stocking rate of 3,500 per square foot and intensive management practices. These bins are fed 1 gallon of processed food, three times a week. They are also turned weekly to aerate the bins. These bins are also regularly split in half to stimulate hatching.

This design has several benefits:

1. The concave walls allow for easy turning of the material in the bin to increase oxygen.

2. The worm population is divided into a relatively small unit that can be individually monitored. If one bin has a problem it can be localized and the entire population is not affected.
3. The movable rack allows us to take a bin outside if it develops an odor problem.
4. The shape of the bins being smaller as it goes down facilitates higher breeding due to the fact that the worms are more congested when they are not on top feeding.

Starting a breeder bin:

To start a breeder bin we fill the bin to about half full with shredded paper that has been soaked in water and drained until it is still quite damp but not too wet. We add 5000 or so worms and let them sit for a day or two. At this amount of worms the bin will only need to be fed about ½ gallon of processed food per week. The bin should be gently turned every week to keep good airflow. If the food from the previous feeding has not been eaten, wait to feed.

Watering, turning and feeding:

The top layer of paper should always be damp. A spray bottle of water works well for this. Do not soak but lightly spray the top layer daily. It is a good idea to start with a new bottle and mark it "Worm Water Only." This will prevent you from spraying cleaner or other chemicals in the bin.

Before each feeding the area that you are going to feed should be lightly turned to provide good aeration. Gently pull the paper back and turn the material up from the bottom. If you find a bad odor it is probably a result of the bin being too wet. You can add some dry paper to the bottom of the bin to remedy this. If you find uneaten food, simply cover it with clean damp shredder paper and the worms will take care of it soon enough.

When we feed these bins we pull a layer of paper back from one half of the bin, (either the front half or back half) and spread the food out in a thin layer of 1 inch or less. The paper is then spread back over the food to cover it. The next time this bin is fed the other half of the bin will be fed. This always gives the worms a place to go and gives the food a chance to be completely eaten before you feed that half again. Eventually the paper will be too decomposed to pull back a section. Feed on top of the paper in the same way, only feeding half the bin and cover with 2 inches of fresh damp paper. This will continue to happen and you will have several layers until the bin is nearly full. At this point your worm population should be close to 30,000.

Once worm population reaches 20,000-30,000 worms they should be able to consume 3 gallons of food per week.

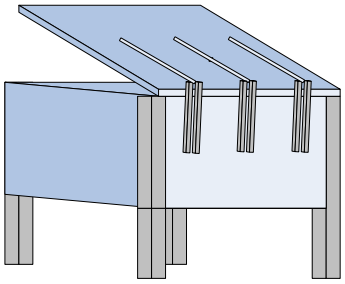
Splitting the bins:

When the breeder bins reach a population of 30,000 or more worms it is time to split the bin. It is best to stop feeding for about a week prior to splitting the bins. This will allow the food to be consumed and makes the process much nicer. The easiest way to split the bin is to fill a new breeder bin with about 3 inches of clean damp paper and take half of the contents, castings, bedding and worms and spread it evenly across the paper in the new bin. Cover with clean damp paper.

If you are trying to establish a breeding program, it is important not to remove the castings from the breeder bins as it contains thousands of cocoons. By spreading the castings across clean bedding the cocoons will begin to hatch out and the bin will refill with worms. The new bin should be allowed to rest for a day or two before feeding. Once a series of breeder bins are established you can expect to be splitting them every 1 ½ to 2 months. The split bins with 10-15 thousand worms will quickly spread out and lay cocoons and within 30 days you will have lots of baby worms. These will quickly grow as you feed.

See Appendix B for a daily management sheet that can be posted above the breeder bins.

Flow Through Reactors



Flow through reactors were originally created by Professor Clive Edwards of The Ohio State University and Dan Holcomb of the Oregon Soil Corporation. Many variations of this system are for sale on the market. The key to the design is that food waste and layers of bedding are added to the top and as the material breaks down and the worms deposit castings, finished vermicompost settles to the bottom. This material is then harvested from the bottom as it falls through a large screen. These units have the benefits of a higher processing capacity and less labor as there is no turning of the beds.

The drawbacks to this system are that there is a larger population of worms and a higher volume of material. If a unit gets too acidic or develops other problems it is harder to address. Another drawback is that you lose cocoons with the castings and the worms reach a maximum carrying capacity. They also take a lot of worms to function properly. You should not try to start flow through systems until you have a large breeder program up and running.

We have made our flow through bins out of reclaimed food carts that were being scrapped out. There are many different items that could be converted into a flow through reactor or they can be built from wood.

Each unit has approximately 20 square feet of surface area and a 50 cubic foot capacity. These systems are capable of housing 100,000-150,000 worms and have a processing capacity of nearly 75 lbs of waste per week.

See Appendix C for a daily management sheet that can be posted above the flow through bins.

Watering, turning and feeding:

The flow through bins tend to dry out much faster than the breeder bins as they have a constant air flow and the liquid all drains out the bottom. It is essential that the bins get watered daily during the week and get a heavier watering prior to weekends or holidays. We use a pump sprayer like the ones used to spray fertilizer. We give each bin a daily watering until the top paper is wet. You can also use a hose with a nozzle set to light mist.

The bins do not need much in the way of turning but we do spend some time each week working the castings that accumulate around the edges. Gently pull back the paper and scoop the casting and worms from the edges and deposit in the middle of the bin. Cover the edges back with paper. This allows the castings to work its way out the bottom of the bin and put the worms back into the area where they can eat the most food. It also distributes the cocoons and helps to stimulate hatching.

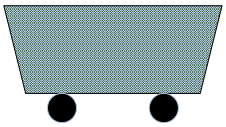
We feed these bins 5 gallons of processed food three times a week. Gently pull the paper back from one half of the bin and check to make sure that the majority of the previous feeding has been consumed. Spread the five gallons out in as thin a layer as possible. Recover with the paper.

Sometimes the paper will be too decomposed to pull back a section. Feed on top of the paper in the same way, only feeding half the bin and cover with 2 inches of fresh damp paper. Although it seems that the bin will eventually overflow, we have had bins in operation for over 18 months and fed thousands of pounds of food without it ever reaching the top of the bin.

Collecting castings:

Our flow through bins have tubs under them to collect the castings that drop through. It is important to collect these regularly at least once a week. Some worms will fall through with the castings and if they are not collected and properly stored they will dry out and die. Also the castings will have some liquid from the bins in with it and it will turn anaerobic if it is left for too long. We put all the castings in a special container that we have for this purpose and allow it to drain. This can be anything as simple as a 5 gallon bucket with holes drilled in the bottom for drainage or as elaborate as a laundry cart bin that has been converted for that purpose. We also place a screen on the top of the castings with food on it to draw the worms that are in the castings

to the top so they can be returned to a bin. The casting should be allowed to cure and dry out for about a week before using.



Miscellaneous Bins:

We have found that it is good to have some miscellaneous bins that can be used for overflow. If you have excess food it is thrown in this bin. The management model is very low maintenance. In our project this bin started out as just one overflow from a bin that had gotten too acidic. We threw the material into this bin, covered it with a large amount of paper and set it outside because it stunk. When we checked it several weeks later it was full of worms. So we kept it going and added other bins as they became available.

We made ours out of discarded laundry cart bins and they are essentially just a big bucket with holes drilled in the bottom for drainage. Although these bins do not have the breeding rate or reproduction capabilities of the other two styles, they are very helpful because as you are managing the other bins, there is always a need to put some material somewhere. The other thing that comes up is you have a breeder bin that needs splitting and you don't have anywhere to put it, in our system, we put it in a laundry bin and let it sit until we have a production bin available. Or if a bin gets smelly, we will put the contents in a laundry bins and cover it heavily with paper and put it

outside and forget about it for awhile. We basically use these bins as bonus bins and treat them as though they do not matter. The idea is that you can feed them heavily and cover with a lot of paper because you have already written them off. At the end of the year we always find that they produce a lot of worms and process a large amount of food.

The only critical management issue is to make sure you give them plenty of water.

Data Entry:

We have found that keeping good records of what is happening in each bin is critical to effective management. Inmates maintain a database that documents how much food is processed in each bin as well as how many gallons of castings and worm tea are harvested. Any additional information or events are also documented. Monthly and quarterly reports are prepared. This allows us to identify the progress that is being made as well as areas that we can improve upon.

(See Appendix D for examples of the spread sheets and the monthly reports as well as samples of daily log sheets.)

Feeding Rates:

There are many systems on the market that make a broad range of claims as to how much material can be processed by the worms each day. Claims range from 50 -150% of the worm biomass daily. The

general rule is that the majority of the food waste should be consumed before adding another layer. The Recycled Organics Unit (ROA) of The University of South Wales did extensive trials to determine maximum processing capacity of different feed stocks. The published report states that a worm bin stocked at 2lbs of worms (+/- 3,000) per square foot can be fed fruit and vegetable waste mixed with cardboard at an average rate of 5 lbs per square foot per week. This rate could be increased as the worm population increases. In our flow through bins that comes out to 100 lbs per week which is slightly higher than what we are currently processing. (20 sq. ft. x 5 lbs =100 lbs)

At WSRU we have found that the surface area and depth of feedstock is critical to the processing capacity. We have experimented with numerous methods of feeding processed fruits and vegetables to the worms as this is our most prevalent food source. Applying a thin layer of 1 inch or less across the entire surface area has given us the best results.

Allowing the air to reach the material and then covering it with shredded paper after a day or two seems to help stimulate the microbial life.

Burying the food too deep or using a layer heavier than 1 inch causes it to clump up and slowly decompose which creates odor problems.

Most fruits and vegetables do well in the bins if they are chopped small and mixed with paper to bulk them up and allow airflow. The worms

seem to prefer finer ground food as it is easier to eat. We have found citrus fruit breaks down very slowly and the worms avoid it so we do not put very much in the bins any more. Melon rinds are the favorite fruit in our bins and for some reason we always get a large hatch when we feed them. There is some documentation on this phenomenon but no definitive reason is given.

Food Supply:

Coordinating with the institutional kitchen to get proper food on a regular basis has been critical to the project. This can be an obstacle as kitchen staff and inmate workers change and there is a need for continuous dialogue. Additionally, the separation of worm "friendly" food waste from the other food waste involves increased workload. Cooperation by staff and inmates is needed in order to reach the goal of processing the majority of food waste.

Paper shredding:

Shredded paper is essential to the worm operation. At WSRU we keep collection bins in all units to get any newspapers that are being thrown away. We also have made arrangements with the library to pick up all their newspapers and any discarded books. Prior to shredding we sort out all the high gloss paper, ads and any staples.

After shredding the paper needs to be soaked in water and then drained well. This takes out some of the ink and gets the paper ready to be used in the bins.

It is a good idea to toss the paper a bit after it is drained to get air back into it before placing in the beds. The point of the paper is to provide air and space for bedding for the worms.

Pests:

Although there are numerous pests documented in the literature we read, at WSRU we only have trouble with two; Fruit Flies and Red Mites.

The fruit flies are more of a nuisance than anything else. They do not hurt the worms at all and the maggots that they breed, although gross to find in the bin, actually help with the processing of food waste. We have found that having a deep layer of bedding on top of the feeding area helps to keep the fly problem in check. We also found that keeping the beds covered with a cloth helps. We experimented with a light spraying of vinegar when the population got high. Although this was effective, we didn't know what long term effect it would have on the pH levels of the beds and so we discontinued the practice.

We currently have several traps made out of plastic bottles and we keep these out on a continuous basis to keep the fly population down.

Red mites are a bigger problem in the bins as some periodicals state that they can be parasitic to worms. We have spent hundreds of hours working in the worm bins and we have never seen a mite attacking a worm so it is possible that the ones we have are not the kind that are harmful. We have not had a large population of them but when we feed heavily with melons we will see some. Red mites tend to gather in groups on the corners of the bins and we have been removing them manually. They look like a bunch of really tiny spiders about the size of the end of a thumb tack. We take a wet paper towel and wipe the lid and sides of the bins where they congregate. Then we throw the paper towel away.

Harvesting:

Although we do not harvest any worms for sale at this point, we do have a need to separate the worms from the castings and separate the casting from the uncomposted bedding material. In order to do this we use a two-step process.

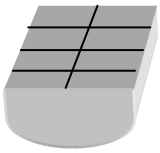
First we take the material to be sorted out of the bins and place on a sorting table. We divide the material into smaller manageable piles about 1 gallon size each. We have a fluorescent light overheard that causes the worms to go to the bottom of the piles. We then hand separate the majority of the worms from the piles by hand. The remaining material is placed in a rotating drum that we made from a 55

gallon plastic barrel with ¼ inch holes drilled in it and open on both ends. This is placed on a cart with 4 wheels that allow the drum to spin freely. The drum is on a slight angle and allows the bedding, worms and any unprocessed materials to fall out the end while the castings fall through the holes. We return the worms and unprocessed material back to a bin and store the castings in a bucket covered with a loose cloth in a cool damp place until it is ready to be used.

Much of these castings will also have worm cocoons in them that may hatch out before you use the castings so it is always a good idea to look through it and pick out any baby worms before using.

Counting Worms:

It is important to occasionally get a count of how many worms are in a bin. Obviously, once you get to substantial numbers it is impossible to count every individual worm so we section off a part of the bin and count the worms in that section and multiply to get an approximate number.



For example we will take a breeder bin and divide it into 8 equal parts. We then pull all the bedding and castings out of one section. We then sort and count all of the worms in that section. It is really important to be gentle during the counting as there will be hundreds of very small baby worms. After we get our count for the one section, we take that

number and multiply by 8 to get an estimate of how many worms are in the bin. So if you had 3,500 worms in the section that you counted you can estimate that you have 28,000 worms in the bin.

(3,500 x 8 = 28,000)

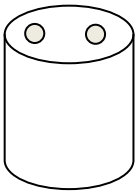
If you feel that your numbers are not accurate you can count more than one section and take an average. In our example above, if you counted two sections and you had 3,000 in one section and 4,400 in the other section, you would have an average of 3,700. (3,000 + 4,400 = 7,400) (7,400 ÷ 2 =3,700) If you multiply 3,700 by the 8 sections you get 29,600 worms for that bin. The more sections you count the more accurate your average will be but you will find that it is far too time consuming to count multiple sections. We have found that counting one section is very accurate.

Building Bins:

One of the most crucial elements of successfully getting a worm program going is to continuously be adding surface area for the worms as the population grows. If you do not increase surface area the worm population will stop growing. The worms reach the maximum carrying capacity for the bins they are in and slow down breeding dramatically. This means that for the first couple of years the worm program is in a regular construction phase. Below is a brief description of each of the bins that we currently use at WSRU with description of how to

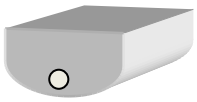
manufacture them. The breeder bins are quite simple and require very little carpentry skill. The flow through bins are more complex and require more advanced skills.

Breeder Barrel Bins



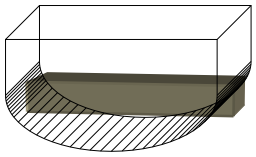
These bins start as a plastic 55 gallon drum.

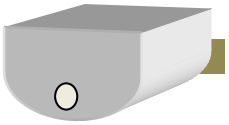
They are then cut in half lengthways so the caps are center on the half bin.



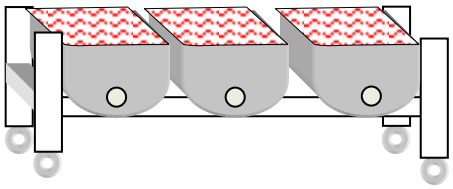
A 2" x 4" x 20" piece of wood is then screwed across the back of the bin to keep it from rocking back and forth and tipping over.

This piece should be flush to the bottom and the bins should be level before screwing in. You must use some caulk or rubber gaskets or the bin will leak at this point.

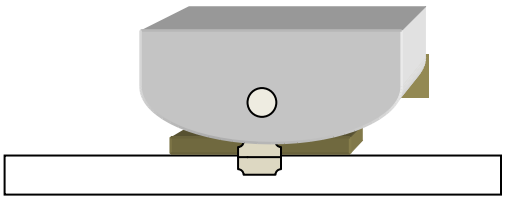




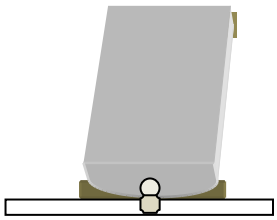
The bins can be used just as they are on anything you want to set them on. We found that it was convenient to make a rack on wheels that holds 3 to 4 of the bins and we work them as a group.



As an added feature you can attach another 2" x 6" x 16" board under the front of the bin and place a large door hinge the connects the 2" x 6" to the rack.

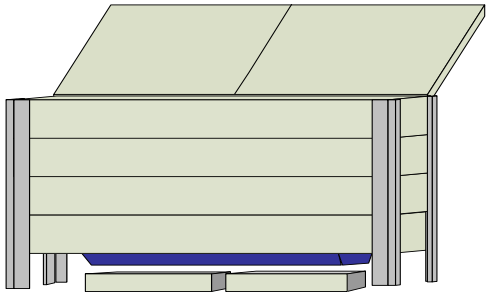


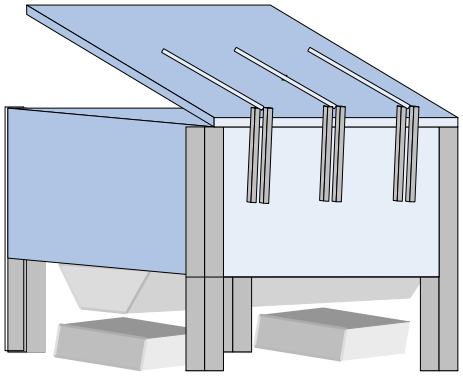
This allows the bins to be tilted up and is good for draining the bin if it gets too wet and is also helpful when you want to take all the material out of the bin.



Flow through Bins

Numerous items that would normally be discarded can be re-purposed into flow through bins or you can make them from a set of plans.
We have designed two different styles of flow through bins at WSRU using different recycled materials. We have used several different materials for the grate or screen at the bottom including heavy duty weed eater line woven like a tennis racket with 2 inch holes and chain link fencing. Both of these have worked great and allow the material to pass through without clogging up.
It is far too complicated to explain how to build a flow through bin for purposes of this manual but we have included drawings of both of our designs as examples.

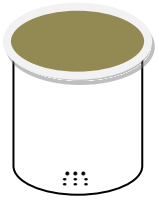




The basic design is a large box with an angled chute at the bottom that allows the material to fall into containers placed under the bins. The bottoms of the chutes have some type of large (2" x 2") screen at the bottom.

Miscellaneous Bins

The miscellaneous bins can be made out of just about anything that will hold material. The simplest bin can be made from a 55 gallon barrels with holes cut in the bottom for drainage and a cover made for the top. It is important to have a good cover as these bins tend to get a little ripe from time to time. (See Covers below)



Another great miscellaneous bin can be made from a discarded laundry cart bin. Simply drill some holes in one end at the bottom.

The nice thing about the laundry cart bin is that if you have a problem bin or some extra food, you can put the material in it, cover it with a heavy layer of wet shredded newspaper and wheel it someplace out of the way and forget about it for a few weeks. You will probably be amazed at how many worms you find in it when you check on it. We made large wooden covers for a couple of our laundry cart bins that had a four inch lip all the way around. This works well for keeping odor contained and moisture in.

Covers:

Covers are important for the breeder bins and the miscellaneous bins. (The flow through bins have lids so no additional covers are needed.) The covers help with odor, retain moisture and help keep down fly infestations. If we had used the upright 55 gallon barrels we probably would have used an elastic band to hold it on the barrel.

We used scrap cloth and made cloth covers for the breeder bins. These are simply spread over the bins when they are not being worked on.

For the laundry cart bins, we manufactured lightweight wooden covers that completely covered the bins and had a four inch lip that overhangs the bins. This provides extra protection as these bins tend to be fed heavier.

Literature:

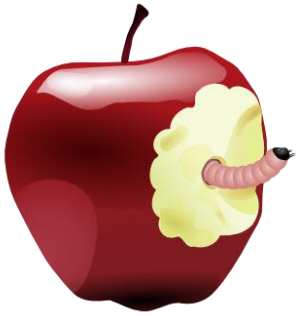
Various books, manuals, reports and articles were obtained by inmates working on the project. (See Appendix E for a list) There are two main areas of interest in the vermiculture field. The first is focused on producing worms for sale as bait. This group looks to maximize worm production and concentrates their energy on getting the worms to breed as fast as possible and grow to the largest size prior to sale. As bait worms are sold by the pound these are important goals. In this model, the by-product of fertilizer is an added value but the primary focus is on worm production and sales. More labor intensive practices are viable because the profit margin on worm sales is extremely high.

The second area of interest is producing and managing worms for waste processing. These groups are primarily focused on developing systems that maximize the processing capacity of worms. In this model the goal is to get the worms to eat material that would otherwise have to

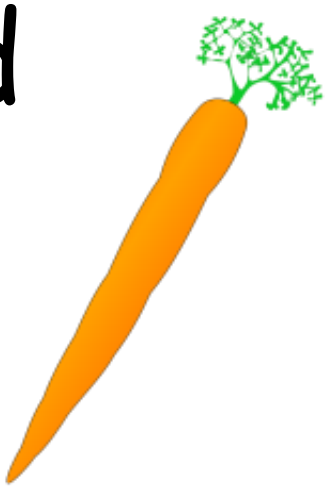
be disposed of at a considerable cost. A major consideration is to develop low labor systems to make the process economically viable.

Among these two areas there is some information that is fairly standard throughout the various literature and other data varies greatly depending on what source you read and what area of interest the author is focused on. At the WSRU project, we tried to employ practices from both fields to maximize worm production as well as processing capacity.

Table of Appendices



Worm Food



Please save all fruits and vegetables for the Vermiculture program.

Apples (whole or cores)

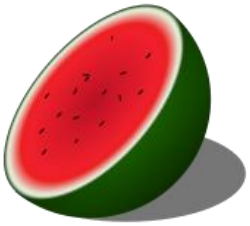
Oranges

Bananas (or peels)

Carrots

Celery

Melons

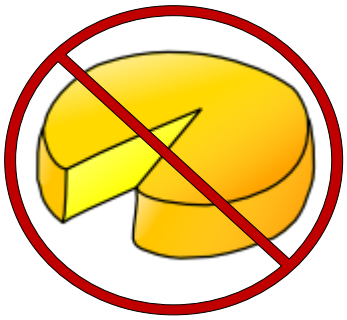


Salad Greens

Mixed vegetables

<u>Please do not put any meats, breads or cheese or other garbage in the bins.</u>

Thank you!



Appendix B: Breeder Bin weekly management sheet

Breeder Bin weekly management		
Task	Description	Times per week
Food collection	Go to IK and pick up food. Take to wormery and dump food in cart. Wash out cans for return to IK.	5
Food processing and clean up	Process food through shredder if available. If you do not have a shredder, place food in a 5 gallon bucket 1/3rd full and smash and chop with a flat nosed shovel. Clean cans, carts and shredder. Hose down outside area and clean up.	5
Turning breeder bins	Remove covers and trays from bins. Gently turn material over mixing paper and castings. Allow material to air dry for 20-30 minutes. Replace with new paper on top. Put trays and covers back on.	3
Feeding breeder bins	Remove covers and trays from bins. Pull paper back from half of bin to be fed. If old food is not mostly consumed do not feed. If food is mostly consumed, feed light layer no more than 1 inch thick. Replace paper, trays and covers.	3
Watering all bins	Remove covers and trays and open lids. Lightly water with spray bottle to get paper damp (not soaked). Replace covers, trays and close lids.	5
Collecting paper/books	Go to units, education and library with cart and pick up recycled paper from bins.	1
Shredding paper	Separate out high gloss paper and staples. Run through shredder and put in designated bins. Soak with water and let drain.	1
Monitoring ph, temp. and moisture all bins	Use monitors to check and record for each bins.	1
Cleaning	General cleaning, sweeping and mopping of area.	5
Splitting tea bins	Approximately every month each tea bins needs to be split to facilitate maximum breeding rates. Gently remove half of material to new bin. Spread the rest of the material out across bottom of tea bin. Cover with new paper.	1 to 2 months

Appendix C: Flow Through Bin weekly management sheet

Flow Through Bin Weekly Management

Task	Description	Times per week
Turning flow through bins	Open lids and secure. Let stand for 10 minutes. Pull paper back from the half of bin with marker. Gently turn material over mixing paper and castings. Replace paper and close lids.	2
Feeding flow through bins	Open lids and secure. Let stand for 10 minutes. Pull paper back from one half of bin. Feed 4-5 gallons. Spread food out. Put feeding marker on side fed. Replace paper and close lids.	3
Watering bin	Open lids. Lightly water to get paper damp (not soaked). Close lids.	5
Collecting castings	Remove trays from under each bin and dump into sorting tank. Scrape tray with dust pan. Allow liquid to drain into tote and empty. Mop under bins. Replace trays.	5
Sorting worms from castings	Place castings on sorting table under fluorescent lights. Allow worms to move to the bottom. Gently brush off the top material until you reach worms. Let sit for 10 minutes to allow worms to go down further. Repeat process until you have a ball of worms at the bottom. Place worms in bins quickly and spread them out as they are stressed. Hand sort through rest of pile looking for any worms that were missed.	1
Monitoring ph, temp. and moisture all bins	Use monitors to check and record for each bin.	1
Cleaning	General cleaning, sweeping and mopping of area. It is important to mop under and around the trays that collect the castings as these can become an odor problem.	5

2011 Soil Test Results and Comparison														
Material/Source	Phosphorus	Potassium	Calcium	Magnesium	Zinc	Manganese	Copper	Iron	Boron	Nitrogen	Sulfur	Sodium	Carbon	C:N Ratio
	P	K	Ca	Mg	Zn	Mn	Cu	Fe	B	N	S	Na	C	
Castings-WSRU	**900**	**3,200**	**6,900**	**1,000**	**36**	**31**	**11**	**1,072**	**5**	**4,000**	**700**	**700**	**0**	**23**
Biocompost	333	459	4,942	822	*53*	*126*	0	61	*6*					
Organic Compost	200	895	5,618	857	14	*36*	0	11	4					
Miracle Grow potting soil	92	652	1,650	676	3	0	*44*	0	5					
Local Farm sandy soil	44	202	878	133	4	12	0	9	0					
VPPSA	204	1,257	4,832	681	12	22	0	7	2					

* Notes

All figures for the WSRU sample are as received. The microbial advantage of worm castings in the fresh/wet form makes drying counterproductive.

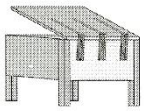
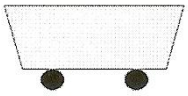
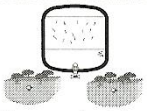
Underlined, italicized figures represent a sample that was higher than the WSRU castings in that element.

All figures are at parts per million (PPM) unless specified.

Wormaponics comparison														
Castings-WSRU	**900**	**3,200**	**6,900**	**1,000**	**36**	**31**	**11**	**1,072**	**5**	**4,000**	**700**	**700**	**0**	**23**
Recommended concentration for hydroponics	30-90	200-400	150-400	25-75	.02-.2	.1-1.0	.02-.2	.5-5.0	.1-1.0	70-300	60-330			
Our casting diluted 10-1 in a tea.	90	320	690	100	3.6	3.1	1.1	107.2	0.52	400	70			
Our casting diluted 20-1 in a tea.	45	160	345	50	1.8	1.55	0.55	53.6	0.26	200	35			

WSRU Vermiculture Program

February 2012 Monthly Report

 Tea Bins (25)	Total Food Added	170.0 Gal.	1020.0 lbs.	 Flow-Through Bins (05)	Total Food Added	360.0 Gal.	2160.0 lbs.
	Average per bin	6.8 Gal.	40.8 lbs.		Average per bin	36.0 Gal.	216.0 lbs.
 Laundry Cart Bins (8)	Total Food Added	64.0 Gal.	384.0 lbs.	 Wormaponics bins (2)	Total Food Added	10.0 Gal.	60.0 lbs.
	Average per bin	8.0 Gal.	48.0 lbs.	Tea Production	Total Tea Produced	50.0 Gal.	
					Total Tea Exported	0.0 Gal.	
				Castings harvested from all bins		42.0 Gal.	189.0 lbs.

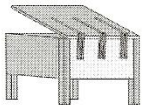
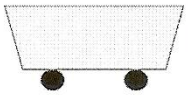
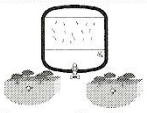
Monthly Totals for all Bins

Total Food Waste Processed	934.0 Gal.	5604.0 lbs.
Total Paper Received and Processed	20.0 Cu Ft.	1500.0 lbs.
Total Casting Harvested	42.0 Gal.	336.0 lbs.
Total Tea Produced	50.0 Gal.	
Beginning Worm Count	2,695,000	
Ending Worm Count	2,815,000	

Notes*

This month we worked added two more Flow Through bins bringing the total to 12. (Although the last two are not in operation yet.) As this represents the last two food cart units we spent some time designing and building a prototype of a new Flow Through bin using recycled materials from the mattress factory. The prototype looks really god and should be easier to work with. We also started working on several projects in preparation for expansion of the program. We are still struggling with fruit flies and although the nematodes are helping they have not proved to be a quick fix. We split several of the breeder bins and are in the process of building 25 more so that we will have a worming population of 1 million breeders in 50 bins. If we can get on a regular splitting schedule we should have in excess of 1 million new worms each month. We are still struggling with getting more time to focus on projects and bin management. We also spent quite a bit of time this month worming on an operations manual that can be exported to other units.

WSRU Vermiculture Program

Quarterly Report 4th Quarter 2011 (Oct-Dec)							
 Tea Bins (25)	Total Food Added	546.0 Gal.	3,276 lbs	 Flow-Through Bins (08)	Total Food Added	576.0 Gal.	3,456 lbs
	Weekly Average per bin	1.7 Gal.	10.1 lbs.		Weekly Average per bin	5.5 Gal.	33.2 lbs.
 Laundry Cart Bins (10)	Total Food Added	216.0 Gal.	1,296 lbs	 Wormaponics bins (2)	Total Food Added	24.0 Gal.	144.0 lbs.
	Weekly Average per bin	1.7 Gal.	10.0 lbs.	Tea Production	Total Tea Produced	560.0 Gal.	
					Total Tea Exported	50.0 Gal.	
				Castings harvested from all bins		170.0 Gal.	765.0 lbs.

Monthly Totals for all Bins		
Total Food Waste Processed	1734.0 Gal.	10,404 lbs
Total Paper Received and Processed	41.0 Cu Ft.	3,075 lbs
Total Casting Harvested	170.0 Gal.	765 lbs.
Total Tea Produced	560.0 Gal.	
Beginning Worm Count	1,400,000	
Ending Worm Count	2,450,000	

Notes*

This quarter has seen tremendous growth in the vermiculture project. At the beginning of this quarter we had 2 Flow through bins representing a surface area of 40 square feet. We now have 8 Flow through bins with a surface area of 160 square feet. We have also added 3 tea bins bringing the total to 25. The tea bins house a population of nearly 500,000 worms and are managed for breeding purposes. In this quarter we have split those bins twice and used the excess worms to fill the new Flow through bins. The worm population has increased by nearly a million worms. We have also developed a wormaponics prototype and did a small trial to show the viability of growing plants hydroponically using worm tea as the nutrient source. We also conducted three other trials this quarter; two breeding trials, and a hatching trial. Our food intake has nearly doubled this quarter and we now have the capacity to take over 5,000 pounds a month. In addition, we put a great deal of time into making the building look better.

Appendix E: Reference Sources and Printed Materials

Although there are numerous articles and information sites online, there is relatively little written material on the actual practices of processing institutional food waste using vermiculture. The best information we have found so far is listed below.

Vermiculture Technology, Earthworms, Organic Wastes and Environmental Management, by Dr. Clive A Edwards, Norman Q. Arancon and Dr. Rhonda Sherman. CRC Press (2010) –This is a very expensive book but it is the Bible on vermiculture. It covers all aspects of vermiculture from a scientific perspective.

Manual of On-Farm Vermicomposting and Vermiculture by Glen Munroe.

This 39 page manual is available as a free download on-line and is extremely helpful. It provides a general overview of on farm management and documents several on-farm trials.

Processing of Commercial and Industrial Organics and Vermiculture Systems(2007)

Best Practice Guideline to Managing on-site Vermiculture Technologies (2002)

Both of these manuals are published by the Recycled Organics Unit a division of The University of South Wales in Sydney Australia. These manuals are extremely helpful.

Worm Farm Management E. Wilson, Kangaroo Press. (1999)

This is the best book we have found so far. It gives specific insight into obtaining high breeding rates using a 21 day cycle.

Biocycle Magazine - This is a trade magazine that is focused completely on recycling and waste management. Although it is expensive, we have numerous articles that have been very helpful.

ATTRA- The National Sustainable Agriculture Information Services is a division of the National Center for Appropriate Technology. They provide publications for free on numerous sustainable practices and have provided us with various pamphlets including *Worms for Bait or Waste Processing,* Alice Beets (2010). This is a very good general overview and is a great starting point for individuals interested in vermiculture.

Appendix F: Sample Forms

Weekly Food and Paper Intake						
Gallons of Food Received						Cubic Feet of Paper Picked Up
Week of	Mon	Tues	Wed	Thurs	Fri	

Weekly Bin Management –Flow Through Bins and Laundry Cart Bins					Week of _____	
	Gallons of food added					Notes
Bin Name	Mon	Tues	Wed	Thurs	Fri	
FTB #1						
FTB #2						
FTB #3						
FTB # 4						
FTB #5						
FTB #6						
FTB #7						
FTB #8						
FTB #9						
FTB #10						
FTB #11						
FTB #12						
LC # 1						
LC #2						
LC #3						
LC #4						
LC # 5						
LC #6						
LC #7						
LC #8						
Recovery						
Tank						
WB#1						
WB#2						

Weekly Bin Management –Misc. Bins					Week of _____					
Bin Type	Gallons of food added per bin #									
	1	2	3	4	5	6	7	8	9	10
	1	2	3	4	5	6	7	8	9	10

Weekly Bin Management –Tea Bins					Week of _____	
	Gallons of food added					Notes
Bin Name	Mon	Tues	Wed	Thurs	Fri	
TB #1						
TB #2						
TB #3						
TB # 4						
TB #5						
TB #6						
TB #7						
TB #8						
TB #9						
TB #10						
TB #11						
TB #12						
TB #13						
TB #14						
TB #15						
TB #16						
TB #17						
TB #18						
TB #19						
TB #20						
TB #21						
TB #22						
TB #23						
TB #24						
TB #25						

Weekly Tea Production and Casting Harvested						
Gallons of Tea Produced						Gallons of Castings Harvested for the week
Week of	Mon	Tues	Wed	Thurs	Fri	

Vermicompost Tea

Vermicompost tea is an aqueous solution composed of water extracts of solid vermicompost from which microorganisms, soluble nutrients, and plant beneficial substances are converted into a liquid form. Vermicompost tea can be used in a wide range of horticultural and agricultural systems to elicit plant growth and pest and disease management responses through a variety of mechanisms.[1]

The process of making vermicompost tea creates a concentrated organic solution that is high in beneficial microbes and nutrients.

Numerous scientific trials have shown the use of vermicompost tea to promote plant growth, increase fruit weight and have a dramatic effect on plant germination. [2]

Additionally, vermicompost tea has been shown to suppress arthropod pests and parasitic nematodes in plants.[3]

The basic process of making the tea is to dissolve worm castings in de-chlorinated water, add a simple sugar solution and allow the liquid to "brew" by introducing air to the system. This is usually accomplished through an aquarium type air pump. The beneficial aerobic microbes that are found in worm castings multiply by extremely high factors. The finished tea is then able to be sprayed on plants as a nutritional supplement as well as for pest and disease suppression.

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[1] *Vermiculture Technology, Earthworms, Organic Wastes and Environmental Management*, by Dr. Clive A Edwards, Norman Q. Arancon and Dr. Rhonda Sherman. CRC Press (2010) pages 153-154.

[2] *Id*. Pages 246-247

[3] Akhtar M. 2000. *Approaches to biological control of nematode pests by natural products and enemies.* J. Crop Prod. 3: 367-395. Arancon, N.Q. and Edwards C.A. 2004. *Vermicomposts suppress plant pest and disease attacks.* Biocycle March: 51-53

Vermicompost tea is a highly marketed product that is becoming more mainstream among organic and sustainable agriculture farmers. Numerous studies and field trials have shown that when incorporated with other comprehensive natural practices, vermicompost tea can eliminate the need for chemical pesticides, herbicides and synthetic fertilizers.

One of the established benefits of vermicompost tea is the fact that it contains a high amount of trace minerals. There is a growing demand for products with trace minerals in both the organic and conventional farming world. The reason for the importance of trace minerals is that conventional fertilizers only address the NPK needs of soil and over time these trace minerals disappear. Additionally, common chemical herbicides such as glyphosate have been shown to limit the availability of trace minerals.[4]

Many companies such as Ocean Solution, Ocean Trace and GroPal are now marketing supplements that provide these trace minerals. A recent analysis of the castings at WSRU showed it to be relatively high in many of these trace minerals when compared to other typical fertilizers.

Other benefits of vermicompost tea include:

- Increased microbial numbers and activity.
- Does not "burn" plants. It is impossible to over feed plants.
- The microbes in the tea consume and out-compete pathogens.

[4] *Trace Minerals- Beyond NPK*, Zimmer, Gary F. Acres USA Fall 2010

Vermicompost tea is sold in both bottled and "fresh" form. Most literature supports a strong preference for "fresh" tea. This means tea that is actively being brewed and is used within 10 days. The aerobic microbes that are activated and multiplied by the brewing process begin to die off as soon as air is removed from the system. As the aerobic microbes die off they are replaced my anaerobic microbes which are not beneficial to plants. Tea that is sold in bottled form has additives such as citric acid added to suspend the microbes and they usually need to be recharged prior to use.

Like many largely unregulated products in the organic gardening world, the tea is marketed in a wide range of products and prices with an equally wide range of claims. For example three northwest companies that sell vermicompost tea, Yelm Earth, Local Harvest, and Vermico have prices that range from $5 per gallon (Yelm Earth) to $96 a gallon($6 for an 8 oz bottle at Vermico). Local Harvest sells their product in a gallon bottle for $8.50.

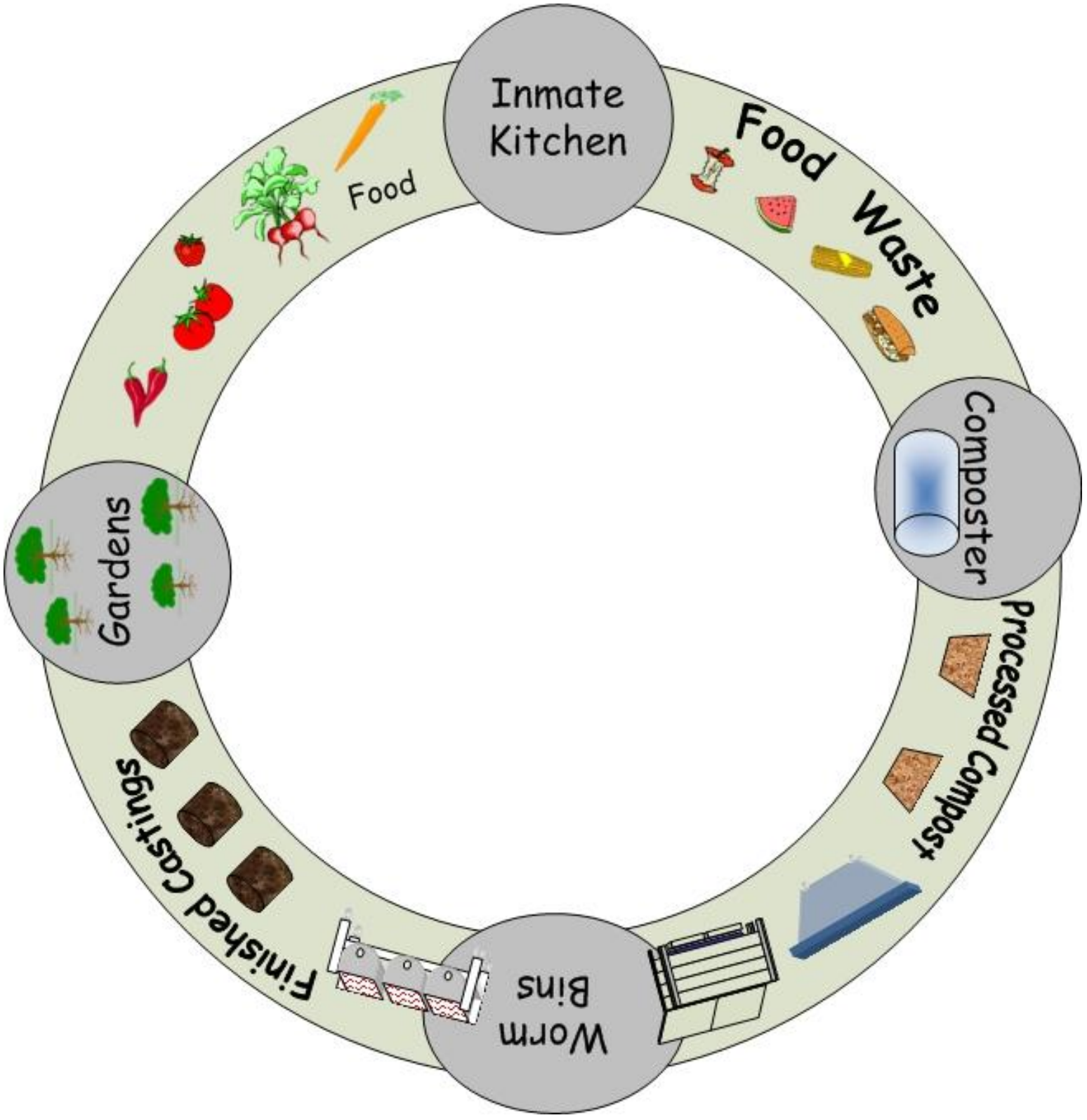
It is important to note that there was a time when worm farming had a very bad reputation and many businesses came under federal investigation for operating pyramid schemes. In the past 20 years worm farming has been replaced by vermiculture and the focus is much more on organic waste management and the beneficial by-products. It is unfortunately still easy to find claims on the internet for worm casting and tea that are simply not true. All of the information provided here is from actual scientific results conducted by universities and established agricultural labs as well as Yelm Earth which is a well known and highly acclaimed company.

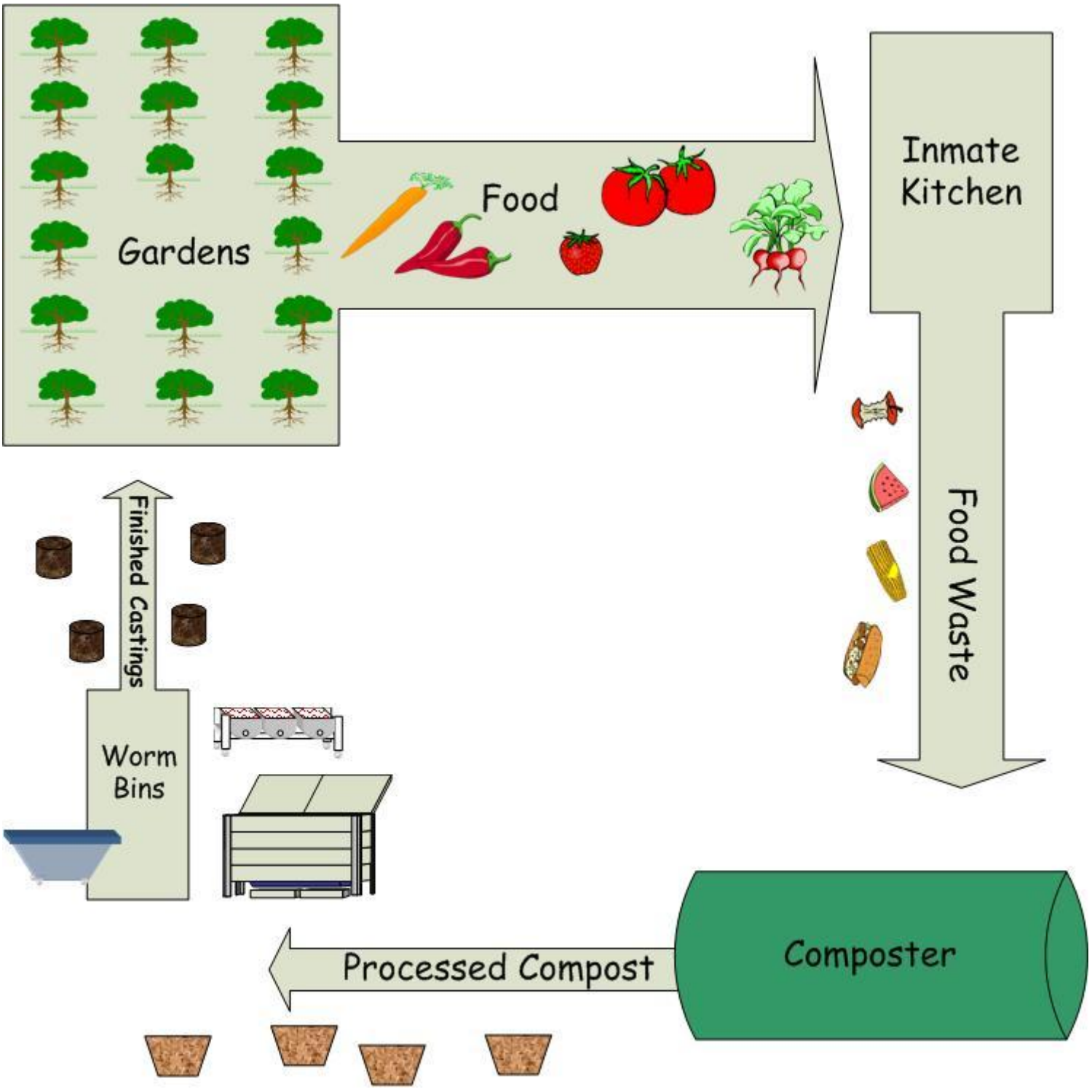
Appendix H: Troubleshooting

Trouble	Possible Problem	Remedy
Bins smell like septic.	Bins are too wet and have become anaerobic.	Pull back bedding and castings to get to bottom of bins. Material will probably be muddy or have standing water. Add dry paper to bottom of bed and spread wet bedding and castings across top of paper. Cover with another layer of dry paper. Turn bed in the next couple of days.
Worms are grouped at top of bins or trying to get out the sides in large numbers. May even have worms on floor.	Feed has started to compost and get hot. Probably from having too thick of a layer of food.	Remove as many worms as possible to another bin. Push material to one side of bins and add wet newspaper to give remaining worms a place to go to. Do not feed bin until all material is consumed.
Bins smell like rotten vegetables.	Too much feed in bin.	If feed is not hot, add heavy layer of wet newspaper to top of bin covering whole bin to eliminate odor. Reduce feeding until food is consumed.
Bins smell like sour milk or rotting meat.	Wrong type of feed stock has been added to bins.	Remove top layer of bedding with as many worms as you can easily get and place material in another bin. Place remaining material in miscellaneous bin, cover well and put outside somewhere out of the way for 1 month. Material should be gone and many worms will have hatched out.
Worms are slow moving and skinny. Bedding is dry.	Bin may be too dry.	Add water to top layer daily until moisture level is 80% - 90%
Worms are stressed and pooling at sides of bin.	Bin has become too acidic, possibly from too much citrus.	Add a heavy layer of fresh wet shredded newspaper to give worms a place to go. Discontinue feeding until material is consumed.

**This trouble shooting guide is also included in the signage section because we have a laminated sheet hanging on several bins with the weekly bin management sheet on one side and the troubleshooting on the other.

Appendix I: Other Signage



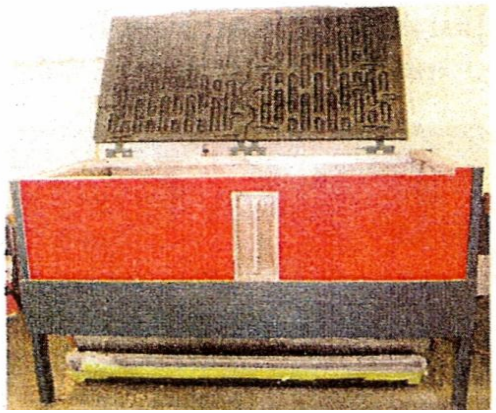

Gardens
Food
Inmate Kitchen
Food Waste
Finished Castings
Worm Bins
Composter
Processed Compost

Fruits and Vegetables

Thank you

VERMICULTURE

- $3 0,000± annual cost reduction for food waste disposal service from the institutional kitchen.
- Reduction in landfill material waste.
- No fuel cost to transport waste.
- Production of high quality organic soil amenity for soil enhancement.
- No fossil fuels used in production.
- Generation of approximately 50,000 pounds of fertilizer used in institutional gardens annually.
- Development of a Best Practices manual for worm production in an institutional setting.
- Expansion to state institutions will have a tremendous impact on natural resources.



Commercial style worm bin made from recycled materials.

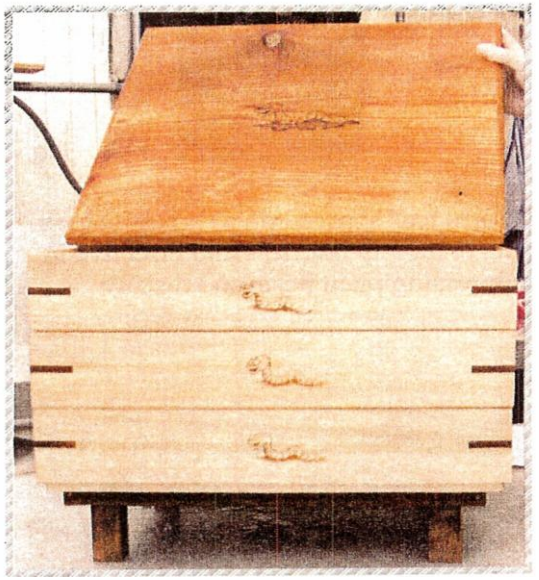
A happy worm is a productive worm!

2011

Monroe Correctional Complex
16550 177th AVE SE
PO Box 777
Monroe, WA 98272

SUSTAINABILITY

Monroe Correctional Complex is converting food waste (or garbage) into organic fertilizer through on-site intensive Vermiculture.



BENEFITS

Verrnicornposting removes harmful pathogens.

The Soil Ecology Laboratory at Ohio State University conducted studies showing that worm casting fertilizer outperforms traditional compost.

These are nontoxic materials that are more valuable to agricultural crops than their chemical counterparts.

Worm tea barrel

"Worm tea" sprayed on as a pesticide is safe, relatively odorless and effective in suppressing plant pests and disease.

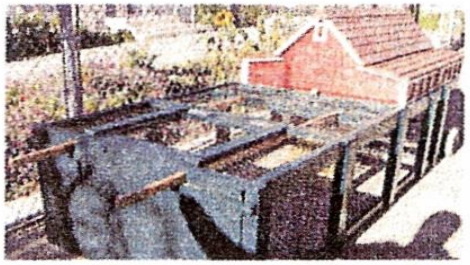
AWARENESS

A series of trials were conducted to determine best practices for maximizing worm

Red worm egg capsules producing more worms

Food chopper / Newspaper shredder

An entirely new and previously untapped market could be established that would provide for employment



FUTURE PROJECT

Worms to Chickens

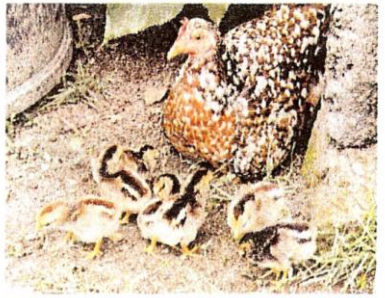
Introduce chickens to determine if worms can be used as a high protein food source.

If successful, the study will produce an inexpensive and reliable food source for poultry and other livestock.

The project will involve offenders, local farmers, veterinarians, a farm supply store, local highs school educators, and

OUTCOME

- Production of 6,000± pounds of high protein livestock feed annually.
- Comparison of chicken health and egg production on a worm diet.



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Worms are stressed and pooling at sides of bin.	Bin has become too acidic, possibly from too much citrus.	Add a heavy layer of fresh wet shredded newspaper to give worms a place to go. Discontinue feeding until material is consumed.

Flow Through Bin Weekly Management

Task	Description	Times per week
Turning flow through bins	Open lids and secure. Let stand for 10 minutes. Pull paper back from the half of bin with marker. Gently turn material over mixing paper and castings. Replace paper and close lids.	2
Feeding flow through bins	Open lids and secure. Let stand for 10 minutes. Pull paper back from one half of bin. Feed 4-5 gallons. Spread food out. Put feeding marker on side fed. Replace paper and close lids.	3
Watering bin	Open lids. Lightly water to get paper damp (not soaked). Close lids.	5
Collecting castings	Remove trays from under each bin and dump into sorting tank. Scrape tray with dust pan. Allow liquid to drain into tote and empty. Mop under bins. Replace trays.	5
Sorting worms from castings	Place castings on sorting table under fluorescent lights. Allow worms to move to the bottom. Gently brush off the top material until you reach worms. Let sit for 10 minutes to allow worms to go down further. Repeat process until you have a ball of worms at the bottom. Place worms in bins quickly and spread them out as they are stressed. Hand sort through rest of pile looking for any worms that were missed.	1
Monitoring ph, temp. and moisture all bins	Use monitors to check and record for each bin.	1
Cleaning	General cleaning, sweeping and mopping of area. It is important to mop under and around the trays that collect the castings as these can become an odor problem.	5

Trouble	Possible Problem	Remedy
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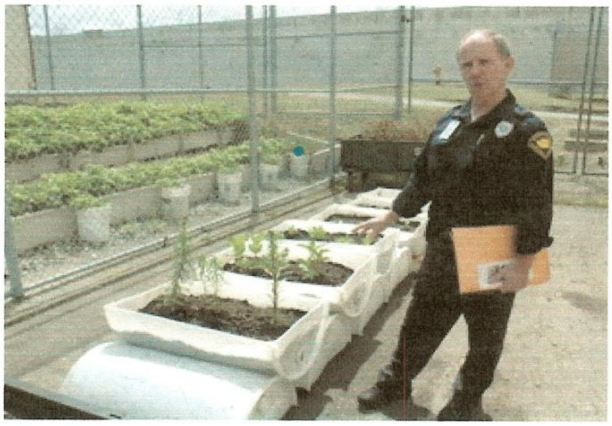
Breeder Bin weekly management

Task	Description	Times per week
Food collection	Go to IK and pick up food. Take to wormery and dump food in cart. Wash out cans for return to IK.	5
Food processing and clean up	Process food through shredder if available. If you do not have a shredder, place food in a 5 gallon bucket 1/3rd full and smash and chop with a flat nosed shovel. Clean cans, carts and shredder. Hose down outside area and clean up.	5
Turning tea bins	Remove covers and trays from bins. Gently turn material over mixing paper and castings. Allow material to air dry for 20-30 minutes. Replace with new paper on top. Put trays and covers back on.	3
Feeding tea bins	Remove covers and trays from bins. Pull paper back from half of bin to be fed. If old food is not mostly consumed do not feed. If food is mostly consumed, feed light layer no more than 1 inch thick. Replace paper, trays and covers.	3
Watering all bins	Remove covers and trays and open lids. Lightly water with spray bottle to get paper damp (not soaked). Replaced covers ,trays and close lids.	5
Collecting paper/books	Go to units, education and library with cart and pick up recycled paper from bins.	1
Shredding paper	Separate out high gloss paper and staples. Run through shredder and put in designated bins. Soak with water and let drain.	1
Monitoring ph, temp. and moisture all bins	Use monitors to check and record for each bin.	1
Cleaning	General cleaning, sweeping and mopping of area.	5
Splitting tea bins	Approximately every month each tea bins needs to be split to facilitate maximum breeding rates. Gently remove half of material to new bin. Spread the rest of the material out across bottom of tea bin. Cover with new paper.	1 to 2 months

Department of Corrections
WASHINGTON STATE

A Million Worms Could Save a Million Dollars at Monroe Correctional Complex

By Maria Peterson, Communications Consultant



Correctional Officer Art King shows how recycled laundry detergent containers are used to grow produce with organic worm casting fertilizer.

William Camarata digs his hands through a layer of wet shredded newspaper and down through another layer of rich, brown soil that was once food scraps from the Monroe Correctional Complex kitchen. He pulls out a handful of compost soil teeming with worms.

"We have the most pampered worms in the nation," Camarata says with pride.

Camarata proceeds to tell the visitors from Department of Corrections headquarters about the stages of worm development, breeding and composting with knowledge that would rival most experts in the worm composting, or vermiculture, field.

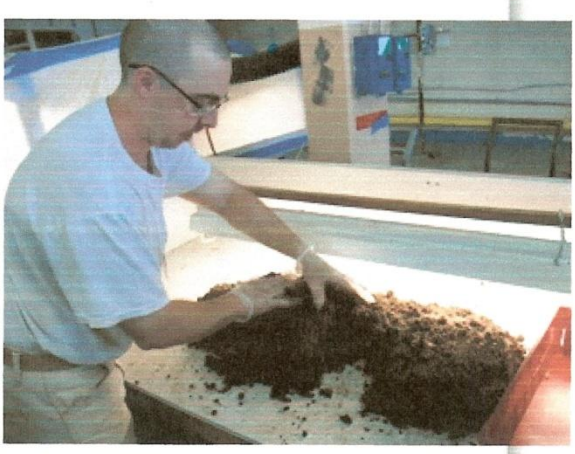
But Camarata isn't a scientist – he's an offender at Monroe who will be incarcerated until 2016. He and one other offender are paid a small wage, just 42 cents an hour, to help maintain this program in the former laundry facilities at Monroe's Washington State Reformatory Unit.

"It's the perfect environment for the worms," Camarata said of the warm, moist building. "It takes 45 days for a cocoon to hatch and if you give them more room they'll just continue to grow."

And grow it has. The program started with just 200 worms, dug from the ground at the Reformatory, and today there are an estimated one million. How do they know? Camarata counted the worms in a large section of the compost bin by hand.

"I stopped naming them after a while," he sez.

The program has reached this success in just over a year, a remarkable time frame by scientific standards. The success is due, in part, to the efforts of offender Nick Hacheney who heard about the program from staff members who were asking for offenders to volunteer to help.



Offender William Camarata uses lights to send the photosensitive worms toward the bottom of a pile of worm castings in order to sort the castings from live worms.

Hacheney was taking correspondence classes about Permiculture, or sustainable systems, at the time and was also interested in vermiculture. His passion about the topic led him to write letters to every college or private sector vermiculture program he could find. The response was overwhelming.

"I have a stack of letters," said Hacheney. "People sent instructions, magazine articles. The scientific community has been really supportive."

Though the agency's new policy prohibiting the use of offender volunteers has kept Hacheney from any hands-on work with the program since February, he sees the impact it's still making on the other people who participate.

"I'd love to be out of prison one day and hear about the program and the guys and the program still going at WSR," he said. "It's easy to feel like your time is wasted here but for us this program caught hold and captured our vision. The sky's the limit for how far it can go."

The worms eat their body weight in food from Monroe's kitchens every two days, which is converted into castings, a rich organic fertilizer that is used to grow produce used in offender kitchens and plants that are given to the city of Monroe. The facility produces between 50 and 100 gallons of castings each week.

Correctional Officer Art King, who is nearing his 30th year as a correctional officer, has seen the positive change in the offenders who participate. King says this program, and others, help improve the safety of prisons by giving offenders something to be involved in, look forward to and create a bond over.

"Once you have a person plant a seed, they want to see it grow," said King. "They wouldn't have talked to each other before, but you put them in the greenhouse together and they have something in common. They're absolutely no trouble when

Monroe Correctional Complex has more than a million "red wiggler" worms that eat discarded food from the kitchens and turn it into organic fertilizer.

they're involved in this."

In addition to the safety improvements, King theorizes that the program could save the state millions of dollars. The program has not used any taxpayer dollars for the materials needed to start the program. The worm breeding cases are modified laundry detergent containers. The flower beds in the garden were made from old mattress cases from Correctional Industries' mattress recycling center and the large vermicompost bin, which retails for about $5,000, was made from an old food cart and recycled material such as scrap wood.

All of the food used in the compost comes from the offender kitchens. DOC would have otherwise paid for the food to be sent to a local recycling facility. The food grown from the castings is fed to the offenders which avoids produce costs. King has a vision that one day the state will hopefully stop purchasing pesticide and instead use "worm tea," an organic fertilizer and pesticide byproduct from worm castings, to spray plants at state facilities.

"I'm not talking thousands of dollars," said King. "I'm talking millions if we can get this operational across the state."

Hacheney said even the offenders are on board. He admits that sometimes the offender population can be resistant to anything that they perceive to be a benefit to the Department, but not in this case.

"We watch the news. We know the state of the budget and we know that programs get cut," he said. "We started this hoping to make a dent in what was coming out of the chow hall and I believe we've shown everyone it's really worthwhile."

But for Hacheney the true benefit is that the offenders who participate can see the whole concept of reform and repairing things that have been damaged – and not just the environment, but also themselves.

"Will (Camarata) could step out of prison and do this for a living," he said. "That's my vision for the future of this program that guys could leave here and make a living off of this and change their lives."

Snohomish Conservation District
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SNOHOMISH
CONSERVATION DISTRICT
The Nexus

Worms on 'The Hill' ~ Monroe's Best Kept Secret

by Lois Ruskell, Information and Education Coordinator

Touring an impressive, commercial-sized worm composting operation in Monroe might seem pretty ordinary, but it wasn't for two other District staff and myself. Had it not been for the background checks, metal detectors, and multiple locked gates, we might have thought we were in a technical college's horticulture building. Not so; this is what's required to get into the worm composting facility at the Monroe Correctional Complex (aka 'the Hill') in Monroe.

The Monroe Correctional Complex has, through the extensive efforts of one officer and several inmates, started a worm composting (or vermiculture) operation to reduce costs in disposing of the prison's kitchen wastes, and to produce compost for the prison's vegetable and flower gardens. Worm compost and worm tea enrich the soil, ward off plant pests, and provide a rich organic fertilizer – all from kitchen scraps.

Above - *the deep purple dahlias growing in a garden at the Monroe Correctional Complex are a stark contrast to the razer wire surrounding the exercise yard.*
Left - *an inmate shows off the worms in one of the breeding boxes in the composting unit.*
More - *see more photos on our Flickr page under 'Extended Nexus' - www.flickr.com/snohomishcd*

The Monroe prison facility contains four units: the Washington State Reformatory, the Twin Rivers Unit, the Special Offenders Unit, and the Minimum Security Unit. Now over 100 years old, the complex (built in 1910) has been added to over the years. It sits on a hill above the City of Monroe, and is known by locals as 'the Hill'. Four kitchens serve all the units, cooking for nearly 7,400 in-

King also believes that this program, and others like it, create a bond between pris-

mates daily. One garden currently supplements the kitchen's produce needs, another will begin producing next spring.

From Waste to Waste Not

So how did worms come into the picture? The Monroe Correctional Complex was spending more than $64,000 a year to dispose of their kitchen food waste. To help reduce costs, in 2010 they contracted with Cedar Grove Recycling, a food and yard waste pickup service. This has cut their annual food waste disposal bill nearly in half - a 49 percent reduction! Corrections Officer Art King, a 30-year prison system veteran who spearheaded the vermiculture program, felt that worm composting could not only further reduce the remaining disposal costs, but also reduce the prison's overall fertilizer bill.

A walkway in the main garden at the Monroe Correctional Complex.

oners and improve the overall safety of the prison community. According to King, "Once you have a person plant a seed, they want to see it grow. They may not have talked to each other before, but you put them in a greenhouse together and they have something in common."

The Wormery

Talking to the two inmates working in the old prison laundry, now the worm factory, it's easy to see not only their passion and pride, but also the knowledge they have about their operation.

Inmate Nick Hacheney was taking a course in Permaculture (an ecological design system focused on sustainability for yards, farms and gardens) when he heard about the worm composting program being started. Since volunteering for it, Nick has read books and articles and communicated with university specialists and others around the country to get the latest information and designs they needed to effectively create compost with worms. "I have a stack of letters," Hacheney says. "People sent instructions and magazine articles. The scientific community has been really supportive."

Inmate Will Camarata is equally passionate about the culture of worms as well as producing worm teas and castings.

Continued on page 2

This flower cart inside the Monroe Correctional Complex benefits from worm tea produced on-site.

Worms on 'The Hill' ~ Continued

What is truly amazing is how the two men have taken prison cast-offs -- old laundry tubs, detergent tanks, mattress-making frames, and food carts -- and refabricated them into effective worm breeding bins, tea brewing vats, and raised garden bins. King estimates that if they had to purchase a unit similar to what they house worms in, it would cost around $5,000.

Growing Worm Population Helps Save Money

The Monroe prison's worm composting program started with 200 donated red wiggler worms in 2010. The inmates now estimate more than 1.5 million worms live in their worm factory. The program's goal is to further reduce the $30,000 annual cost of kitchen waste removal by expanding 'Hill-wide', through all four Monroe correctional units. Currently, a 30-gallon sized container of food scraps is removed from the Washington State Reformatory kitchen daily to feed the ever-increasing population of worms.

Officer King shows off a new, large-capacity worm bin, one of several recently built to facilitate expansion of the program.

The worm castings, which don't smell (but look a lot like very rich soil), are used as potting soil. They act as an organic fertilizer and out-perform traditional compost. More than 100 gallons of worm tea is produced every week. That rich liquid is poured directly on the flowers and vegetables as a natural

fertilizer, or sprayed on leaves as a pesticide. King feels they are capable of producing 50,000 pounds of fertilizer annually, further reducing the Correctional Complex's costs for chemical fertilizers.

Food Production Gears Up

In 2010, inmates working in the gardens grew seven tons of food, including 6,000 garlic plants that now sit drying in a dark, cool room off the gardens. All food is used on-site. Plus, inmates recently won an impressive 23 blue ribbons at the Evergreen State Fair with their produce and flowers.

King has hopes that the horticulture and vermiculture programs can transition from being therapeutic in nature to providing all produce needed for the prison complex. During our visit, we saw long rows of strawberries, onions, beans, squash, cabbage and tomatoes. Rows of sunflowers edged raised beds teaming with more vegetables, flowers and herbs. Birds, butterflies, bees and hummingbirds constantly buzzed around us.

Officer Art King shows off a portable chicken tractor designed and built by inmates at the Monroe complex using recycled materials.

Officer King is also trying to demonstrate how the inmates can grow crops in castoff plastic frames from the prison's mattress production unit, all on top of cement. He would like to see these productive bins line the prison walkways, all fertilized with worm tea and compost.

Adding Chickens to the Mix

One of the most amazing creations we saw was a chicken tractor (a moveable chicken coop) complete with a small red barn on top. It was designed by Nick and other inmates to be highly portable with easy access for clean-

ing waste and collecting eggs. There are no chickens yet, but eventually they would like to conduct research using worms as a high protein food source for chickens. That project will involve offenders, local farmers, veterinarians, a farm supply store, and high school and college educators. The chicken tractor can be moved to different garden areas where the chickens can dig for grubs while fertilizing the ground before the next planting.

The gardens are a huge part of the Monroe prison's sustainability program, as well as a job-training opportunity. One garden is maintained through a program with Edmonds Community College's horticulture program. College instructors teach horticulture classes in classrooms which open out to two greenhouses and another highly productive garden. Offenders learn how to properly take cuttings, grow plants from seeds, collect and store seeds, and other technical aspects of horticulture. One offender told us the greenhouses are new and will help them save seeds and produce more cuttings.

With Corrections Department approval, Officer King plans to expand the gardens and worm composting program to provide most of the vegetables for the complex. To do that, they will need large donations of seeds, cuttings and tools. King feels that they might even be able to produce enough food for community food banks, senior citizens or other local programs.

A sign in the Correctional Complex garden made by the inmates.

For more information on sustainability at the Monroe Corrections Complex, visit: http://www.doc.wa.gov/sustainability/docs/FactSheetMCC.pdf. To contact Officer King, find out more about the prison vermiculture program, schedule a tour or to donate seeds or supplies, contact Donna Simpson at the Monroe Correctional Complex at 360-794-2606. Portions of this article are from an article by Maria Peterson, in 'The Daily Communique'.

THE MONROE MONITOR & Valley News

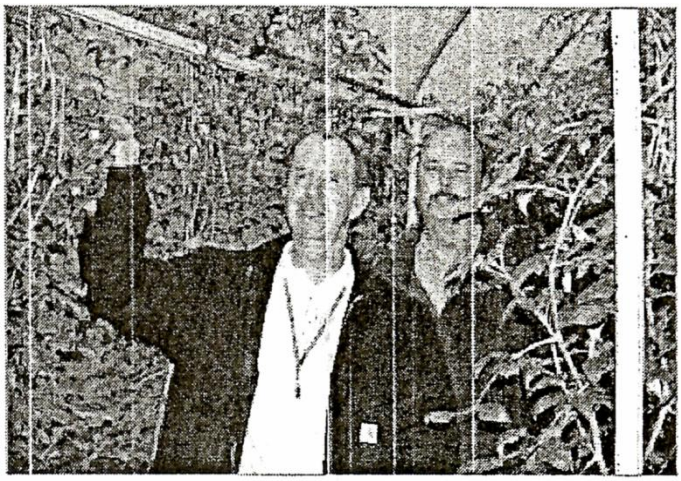
2/20/2012 2:27:00 PM

A wealth of worms: A program at the prison could save taxpayers millions, organizer believes

Potty Keary
Editor

In Art Kings cupped hands is a potential tool to save the state prison system millions of dollars: It could take tons of garbage out of the waste stream leaving prisons. And it could save untold sums on groceries, while making offenders responsible for their own expenses.

"They're called red wigglers," said King. And he returns the handful of earth, riddled with thin plum-colored earthworms, back to a clean white tub in an unused old laundry on the prison grounds.

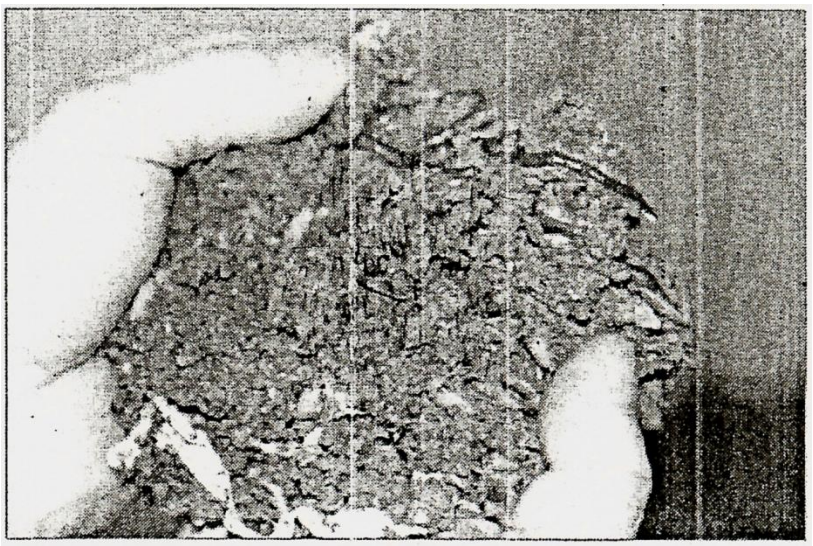


Corrections Officer Art King and Monroe Correctional Complex superintendent Scott Frakes stand amongst cherry tomato plants in a small greenhouse at the prison. One day, King believes inmates will grow all their own vegetables and compost all their own vegetable waste.

Photos by Polly Keary

There are one dozen tubs like it in neat rows in the gray-floored building, each one about the size of a half-ton apple bin. All told, the tubs contain about 2.5 million worms, and they will provide the fertilizer and insecticide that will be the foundation of a farming effort that could one day feed every offender at the Monroe prison complex.

And if all goes well, it could spread to every prison in the state.



A dozen large bins at the prison hold more than two million earthworms that turn tons of food waste into fertilizers and organic pesticide

"It could save taxpayers millions and I'm out to prove it,' said King. The corrections officer is passionate to the point of zealotry on the topic.

After working at the prison for 30 years, h believes he's found a way to relieve some of the burden to taxpayers of the costs of feeding prisoners.

The prisoners, he believes, could grow most of their own vegetables. And they could do it at nearly no cost. For one thing, labor is cheap.

"I believe we have the biggest workforce in the world,' said King. "I believe it's time for them to pay their way while they are here."

And for another, there's no shortage of potential compost Each month, about two tons of vegetable scraps alone head to a landfill from the five prison units that make up the Monroe Correctional Complex.

The prison also has plenty of land that could be used for farming.

One thing it doesn't have is a budget for fertilizers or pesticides. But now it won't need those things. It has worms.

Foggy Bottom Gardens

At the back of the prison complex, nearly up

against the old brick wall that replaced the wooden stockade of a century ago, is an old laundry facility that until recently was abandoned.

Outside the entrance doors is a small terraced garden that spills over with strawberry plants. A colorful, whimsical sign, painted by offenders, proclaims the space Foggy Bottom Gardens.

Also outside are several bins of colorful kitchen scraps; one is brim-full of celery tops, another with carrot peelings and cantaloupe seeds, a third with lettuce scraps.

Inside, the space is mostly occupied by two rows of large white plastic bins with black lids.

Each bin bears the painted image of a worm munching a watermelon rind. There is a brewery smell of fermentation, and a few fruit flies hover in the air in spite of the February chill.

King lifts away a black plastic hinged lid on one bin to reveal a layer of shredded newspaper. Beneath that is a layer of ground-up vegetable waste from the prison kitchens. Dining on that waste are thousands of worms, who are transforming that waste into worm castings, a rich source of organic fertilizer and organize insecticide.

"We take all the newspapers the offenders read and shred them, and the worms eat every bit of it," said King, resting by a bin brim-full with a fluffy nest of shredded newspaper. "Then we take this grinder," --he motions to a tall, yellow funnel-topped object-- "and grind up all the vegetable waste."

The worms make short work of the matter, reducing it all to dark earth. Once the worms have done their work, the contents of the bin are dumped out onto a table and put under a light. The worms flee the light, burrowing to the bottom of the pile, and the worm castings, which look like crumbly moist clay, are moved to a rotating perforated drum.

The drum is spun and the castings screened. Then two gallons of castings are added to 55 gallons of water where it makes a dark brown tea.

That tea contains a range of mineralized nutrients such as silica, nickel, selenium and chromium. It also contains microorganisms that suppress some plant diseases, and that produce an insect repellant when sprayed on plant leaves.

Low cost

The cost of the program to the prison is nearly nil.

Beyond the bins in the old laundry is a stack of hard plastic boards; they are the remains of old mattress frames. With a few scraps of wood and some nails, the boards were transformed into worm bins at acostof$19 per bin.

The rotating drum that sifts the worm castings was handmade out of available materials.

The biggest expense was the produce grinder, which cost about $600.

About a year and a half ago, when King was first getting started, the prison's horticulture program teacher donated 200 worms. Those 200 worms multiplied into the more than 2 million that now fill the bins, potentially producing 50,000 pounds of fertilizer.

The program has already paid for itself in saved garbage disposal costs. Each day, each worm eats about three times its weight in garbage, and that so far has removed two tons of waste per month, saving the prison a couple hundred dollars in 'tipping fees," or garbage pickup costs.

And last year, on less than half an acre of land around the old laundry, Foggy Bottom Garden produced about four tons of food (and won 23 blue ribbons at the Evergreen State Fair).

That's just a fraction of the program's potential, said King.

Potential for expansion

"We should be able to stop sending out any food products in the garbage,' King said. Currently it costs the prison about $30,000 a year to dispose f food waste. That sum could be reduced to nearly nothing, he believes.

And, he went on, there are 200 acres of arable land at the prison. He foresees a day when every vegetable eaten by inmates will be grown on the premises.

King is also seeking grant money to start a chicken program, too, and foresees a time when large rolling cages are moved around the grounds to keep the grass down, replacing mowers while providing the prison with meat and eggs..

Such is his enthusiasm about the worm project that about a year and a half ago he convinced prison administrator Scott Frakes to green-light the program.

"Art said, 'I want to talk to you about where we could go with this," said Frakes, walking through a small greenhouse filled with ceiling-tall cherry tomato plants. "I said. Okay, see what you can do."

In the wake of the murder of corrections officer Jayme Biendi, though, the entire prison was put on lockdown for weeks, and Frakes thought the worm program would probably die for lack of attention.

But King and others kept it going until the prison normalized again.

Frakes said he found the program interesting because of its potential to reduce prison costs. There is one inherent problem; it takes a fair amount of staff time to supervise offender work crews on large-scale farm projects.

But if the savings in food and garage disposal costs outweigh the cost of supervision, then it could be a worthwhile investment, he said.

Other prisons are trying similar things; Walla Walla was increased its agriculture program to the point that it's nearly a commercial-scale operation. McNeil Island has a small but growing agriculture program. And some federal prisons, such as the one at Sheridan, Ore., have been growing vegetables for inmate kitchens for years. .

Other benefits

There are several benefits to the program beyond low-cost food.

The food, if produced using only worm fertilizer and earth, is organic, anti thus healthier than what offenders eat now.

It also reduces a burden on the environment by reducing transportation-related pollution and pesticides.

And according to a recent article in Scientific American, studies show that offenders who work in gardens don't return to prison as frequently.

If Monroe's program goes well, it could be a model for all 13 prisons in the state, said King, whose unlimited enthusiasm sometimes brings a smile to Frakes' face.

But if he smiles at King's visions of raised beds tucked into nearly every corner of the prison and entire hillsides plowed under, he believes there is potential for a good-sized agriculture program at the prison.

"We have a model that works," he said. "We're not far from being able to say we're not sending food waste out ii the garbage anymore. I think there's good opportunities here."